# AGU Fall Meeting Paper Number A33J-3332
# Estimating Uncertainty in Long Term Total Ozone Records from Multiple Sources

Stacey M. Frith, Space Systems and Applications, Inc., Lanham, MD, USA; Richard S. Stolarski, Johns Hopkins University, Baltimore, MD, USA; Natalya Kramarova, Space Systems and Applications, Inc., Lanham, MD, USA; Richard D. McPeters, NASA Goddard SFC, Greenbelt, MD, USA

## 1. Introduction

Long-term ozone records required for time series analysis must be constructed from multiple instrument records of varying type and quality. Also needed are realistic estimates of the uncertainty of the long-term record, including contributions from the individual instrument uncertainty and from the merging process. In this work we estimate uncertainties in the SBUV V8.6 Merged Total Ozone Data Set (updated from *Frith et al.* [2014] through June 2014). With only a single SBUV instrument still in operation, we investigate extending the record with data from AURA/OMI and S-NPP/OMPS nadir-view instruments, and the ramifications on the error analysis. Updated ozone trend results from SBUV V8.6 MOD are shown.

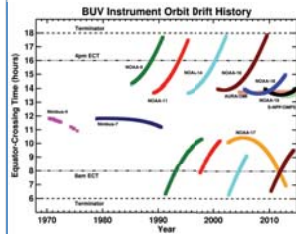## 2. Data intercomparisons demonstrate relative stability of instruments



❖ Continuous coverage of SBUV instruments since late 1978. N19 SBUV/2, AURA/OMI and S-NPP OMPS continue coverage into future.

❖ SBUV measurements are inter-calibrated at the radiance level. Long overlap of OMI and SBUV will help maintain consistent calibration of merged record into future.

**Figure 1.** Equator crossing time of orbits for SBUV satellite series, AURA/OMI and S-NPP OMPS.
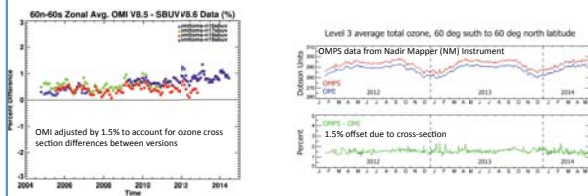


**Figure 2.** 60°N-60°S zonal monthly mean time series differences between OMI-SBUV (left) and OMPS-OMI (right) indicate the overall stability of all three records with respect to each other. OMI ozone cross-sections used in the retrieval differ from those used by SBUV and OMPS leading to a 1.5% offset (will be rectified in next version release of OMI).
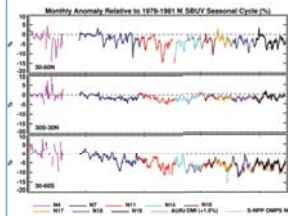


**Figure 3.** Monthly-mean anomaly time series of SBUVs, OMI, and OMPS NM in three broad latitude bands. Coherence of SBUV data supports choice to not make additional adjustments to the data when merging the records for MOD. However variations do exist that must be quantified and accounted for in the error analysis. Aura OMI and S-NPP OMPS have small offsets that vary with latitude.

## 3. Error estimates not sensitive to additional year of data

Following the procedure outlined in Frith et al. [2014] we update the V8.6 MOD error estimates using new measurements from N16 and N19 SBUV. We use Monte Carlo simulations to represent uncertainties in the merged record and test the sensitivity of derived trends to these potential variations. SBUV measurements are inter-calibrated at the radiance level to either N11 SBUV (1994-95) or N17 SBUV (2005-08), whose absolute calibrations have been established independently [Deland et al., 2012]. We mimic this calibration process, but with random offsets and drifts added to each data set to simulate individual instrument uncertainties. We then merge each simulated set of instrument records.
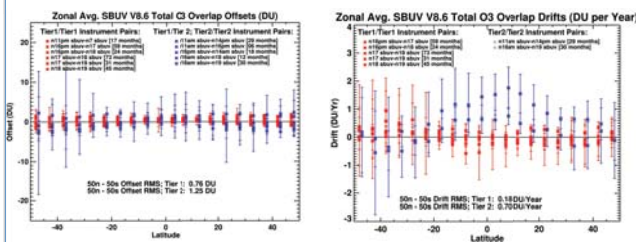


**Figure 3**. Distributions of offset and drift derived from comparisons of SBUV data during overlap periods. "Tier 1" and "Tier 2" values computed to reflect differences in data quality. N14 and the morning ECT portions of N11 and N16 are considered Tier 2 instruments. These values are used in a Monte Carlo model to simulate 10000 sets of potential instrument records with random offset/drift.
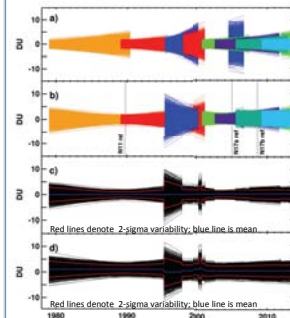


Individual instrument uncertainty simulations. Red/orange instruments calibrated to N11; blue/green to N17 in V8.6 processing.

Individual instrument uncertainties after replicating V8.6 calibration to N11 and N17. Errors grow away from calibration times; are largest in mid-1990s.

Each set of instrument uncertainty simulations is merged following the MOD process to construct 10000 time series of potential MOD uncertainty.

Analysis repeated adding terms for N11/N17 absolute calibration uncertainty in simulations. Distributions were based on Dobson comparisons.

**Figure 4**. Step-by-step error estimation procedure. Panels a-c address relative uncertainty between instruments; Panel d includes absolute uncertainty term.

| Proxy Fit* | 2-sigma Standard Deviation |
|---|---|
| EESC (loss pd.; w/Solar) | 0.22 DU per Year |
| PWLT 1979-1997 | 0.22 DU per Year |
| PWLT 1998-2013 | 0.18 DU per Year |
| Linear Fit 1979-1994 | 0.20 DU per Year |
| Linear Fit 2000-2013 | 0.16 DU per Year |
| *Proxy uncertainties are nearly unchanged with new data | |

**Table 1.** The final step is to analyze each potential MOD error time series with regression model to establish sensitivity of proxy terms to the uncertainty.

## 4. Including OMI improves error slightly as SBUV instruments end
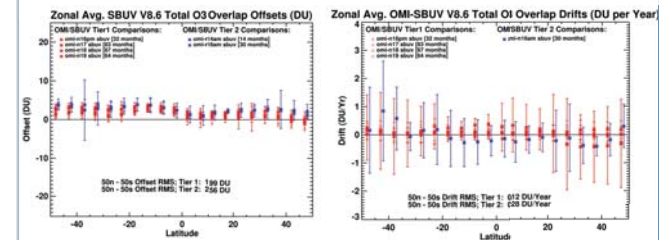


**Figure 5.** OMI-SBUV offsets and drifts for overlap periods as a function of latitude. OMI shows a small positive offset at most latitudes and remarkably stable drift values. Including these values in the error analysis shows a very small but increasing effect as the number of instruments decreases. The 2-sigma error variability (red curves, Fig. 4 Panel c) were reduced by 0.25 DU at the end of 2013 (not shown).

**We do not include OMI or OMPS data in the MOD record at this time as new versions of both are anticipated in the next year.**

## 4. Trends from extended MOD record mixed on indications of recovery



❖ Error bars are root mean square of uncertainty from residual variability and MOD uncertainty.

❖ As found in Frith et al. [2014] EESC fits over the full period (converted to %/Dec for Jan 2000 – Jun 2014) are statistically significant but linear fits over the time period are not.

❖ EESC fits lock in an assumed loss to recovery ratio in the regression. Ideally a linear fit would verify the assumed EESC recovery rate.
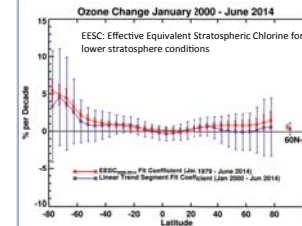
**Figure 6.** Ozone Trends as computed in Frith et al. [2004] updated with one year of N16/N19 SBUV data. Results shown for EESC fit over the full time period and a linear trend fit to data from January 2000-June 2014. Standard terms for seasonal, solar cycle, QBO, volcano and ENSO included; no dynamical terms.

## Conclusions

❖ Aura OMI and S-NPP OMPS NM are quality data sets that can be used to extend the MOD record. New releases of OMI and OMPS are expected in 2015 and will likely be incorporated at that time.
❖ Including calibration and instrument quality information gives a more realistic model of noise in a merged data set which can then be tested for potential interaction with common regression proxies.
❖ Despite a statistically significant fit to EESC, a longer time series is required to detect an ozone increase using a linear trend fit starting in 2000 and thus verify the assumed EESC recovery rate.

## References

Frith, S. M., N. A. Kramarova, R. S. Stolarski, R. D. McPeters, P. K. Bhartia, and G. J. Labow (2014), Recent changes in total column ozone based on the SBUV Version 8.6 Merged Ozone Data Set, J. Geophys. Res. Atmos., 119, 9735–9751, doi:10.1002/2014JD021889.
DeLand, M. T., S. L. Taylor, L. K. Huang, and B. L. Fisher, B (2012),Calibration of the SBUV version 8.6 ozone data product, Atmos. Meas. Tech., 5, 2951-2967, doi:10.5194/amt-5-2951-2012.